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(71) Applicant
Peco Machine Shop & Inspection Services Limited

(Incorporated in the United Kingdom)

Silverburn Place, Bridge Of Don, Aberdeen, AB2 8EG, United Kingdom

(72) Inventor
Joseph Allen

(74) Agent and/or Address for Service
Urquhart-Dykes & Lord
8th Floor, Tower House, Merrion Way, Leeds, LS2 8PA, United Kingdom

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GB 2239676 A GB 2208411 A US 4294573 A

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(54) Multi-phase pumping arrangement

(57) The arrangement is used in a method for pumping a liquid / gaseous phase mixture from an underground reservoir to a process plant, in which the pump arrangement is positionable in a flow line running between the reservoir and the process plant. The arrangement comprises:

a liquid / gas separator GS having an intake for receiving an input supply of the liquid / gaseous phase mixture, and arranged to deliver separated outputs of liquid and gas;

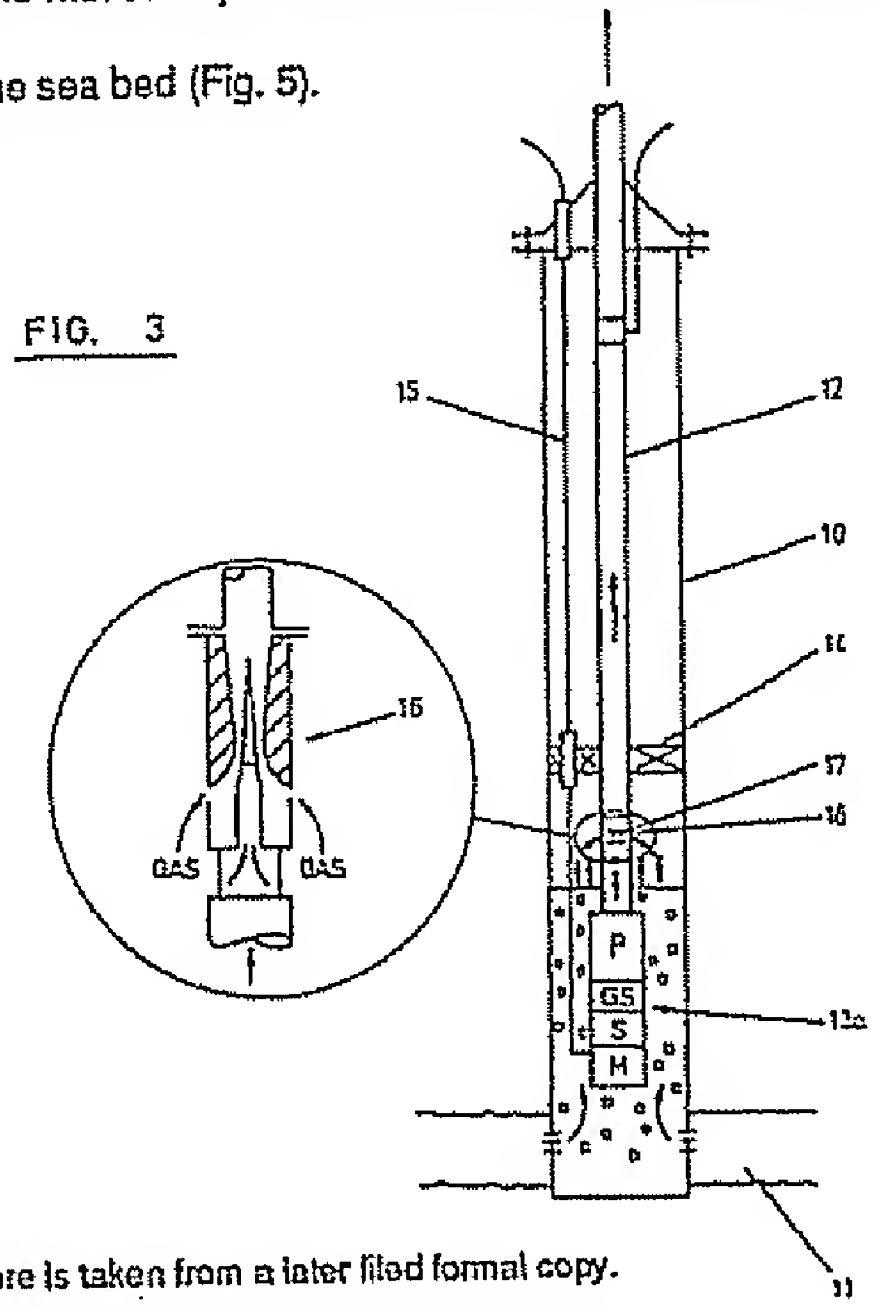
a motor-driven liquid pump P arranged to receive the liquid output from the separator, and to discharge a pumped output of liquid;

a jet pump 16 arranged to receive the pumped output of liquid, and to pass the liquid through the pump prior to discharge of the liquid e.g. into the production pipe 12, after undergoing a pressure reduction by the jet pump; and,

a gas inlet to said jet pump which is communicable with the gas output of the separator whereby the gas can be ingested into the jet pump by the pressure reduction so as to co-mingle with the liquid and be movable with the discharge flow of liquid from the jet pump.

The pumping system may be arranged above the reservoir on the sea bed (Fig. 5).

FIG. 3



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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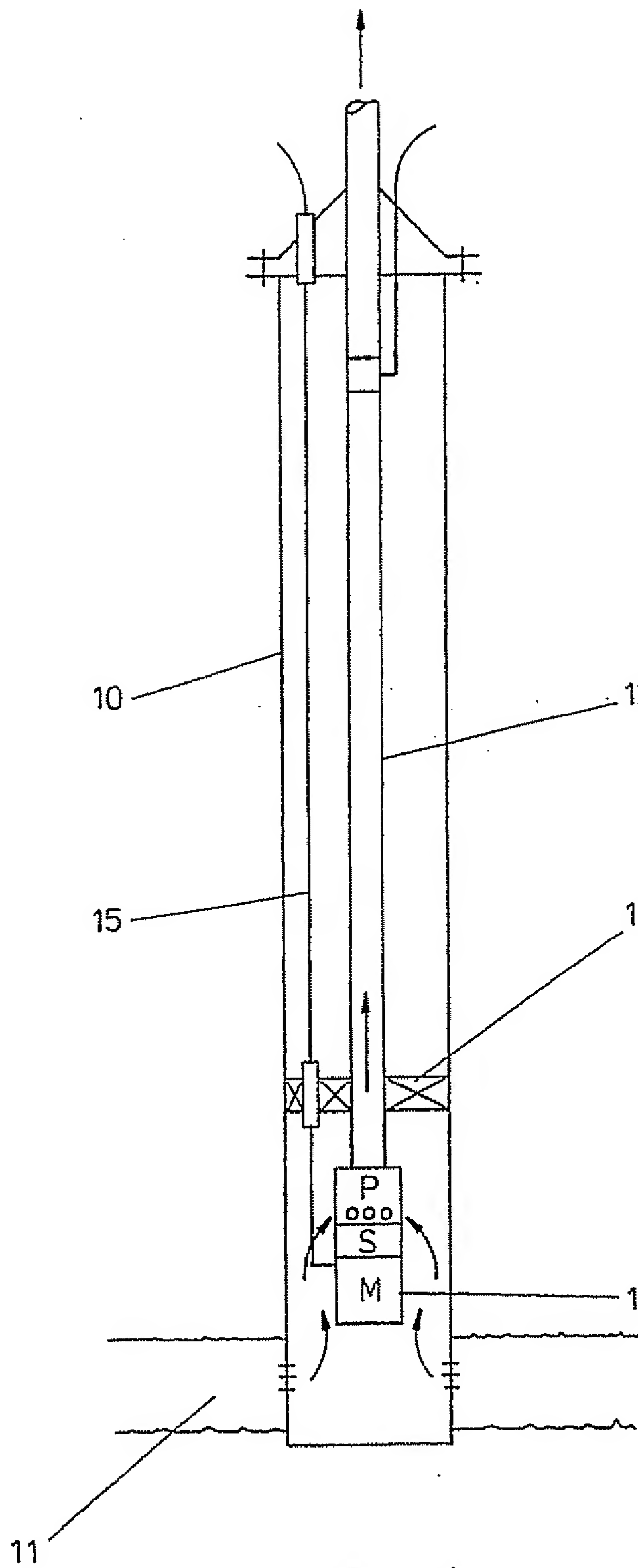

FIG. 1

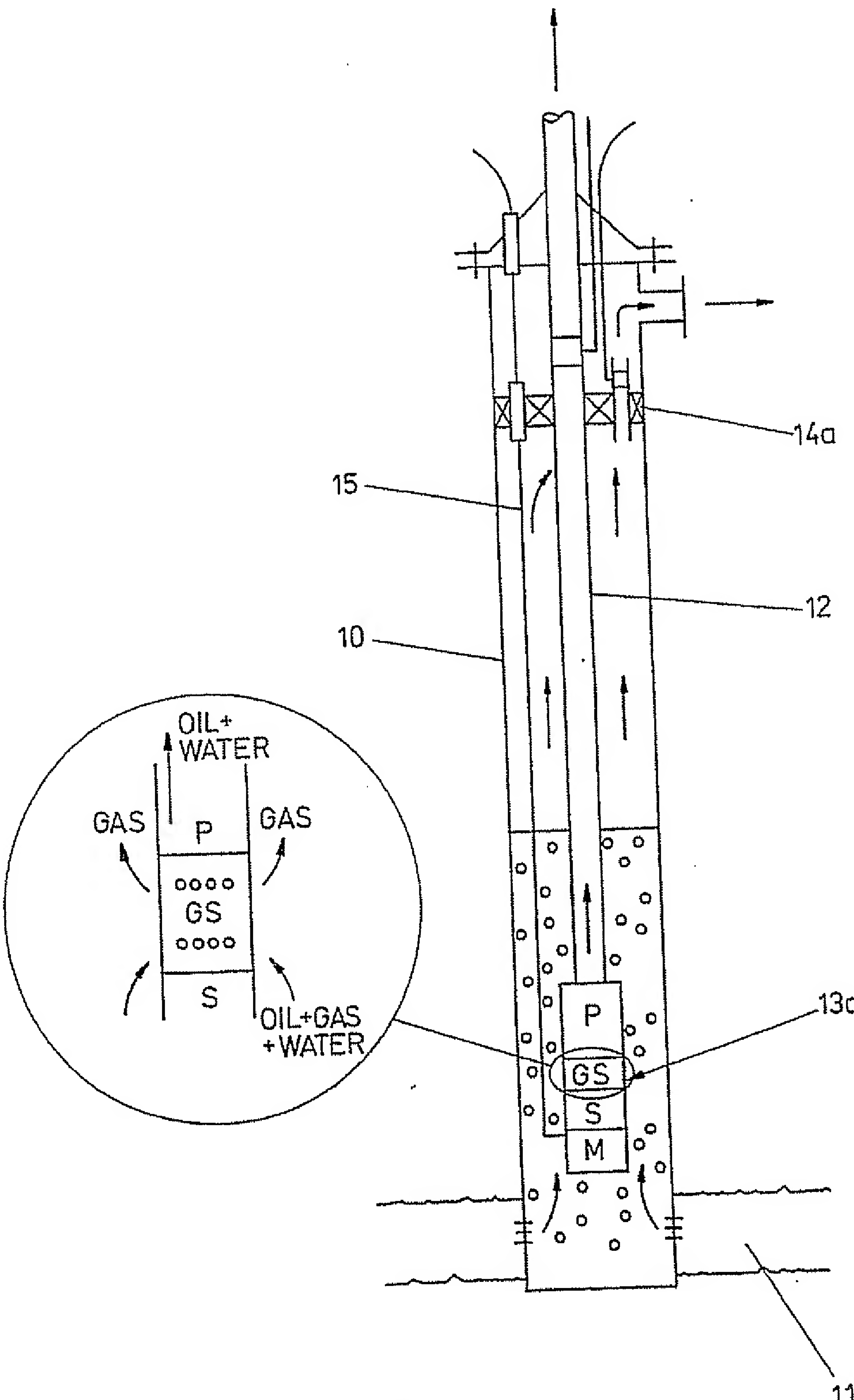

FIG. 2

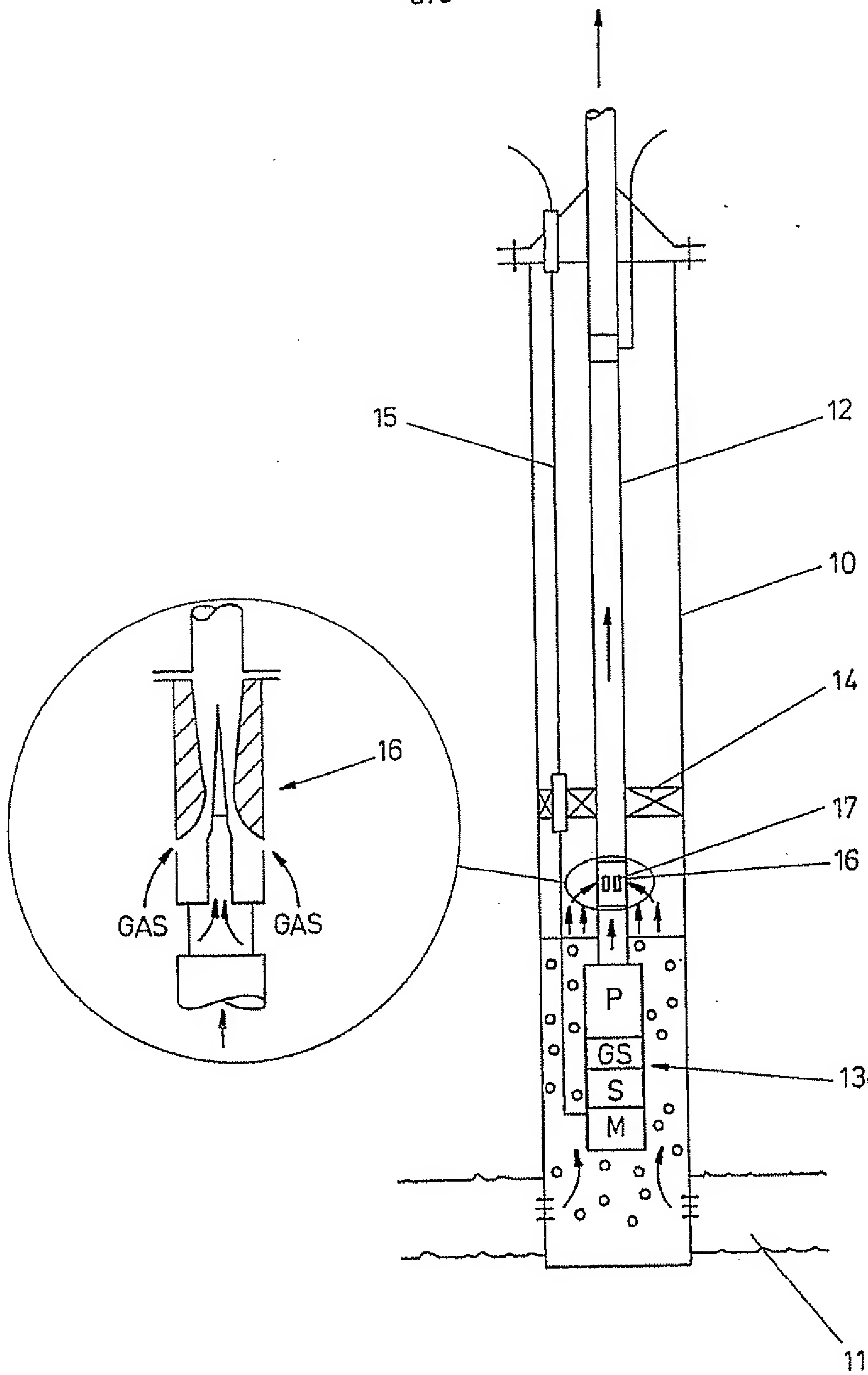

FIG. 3

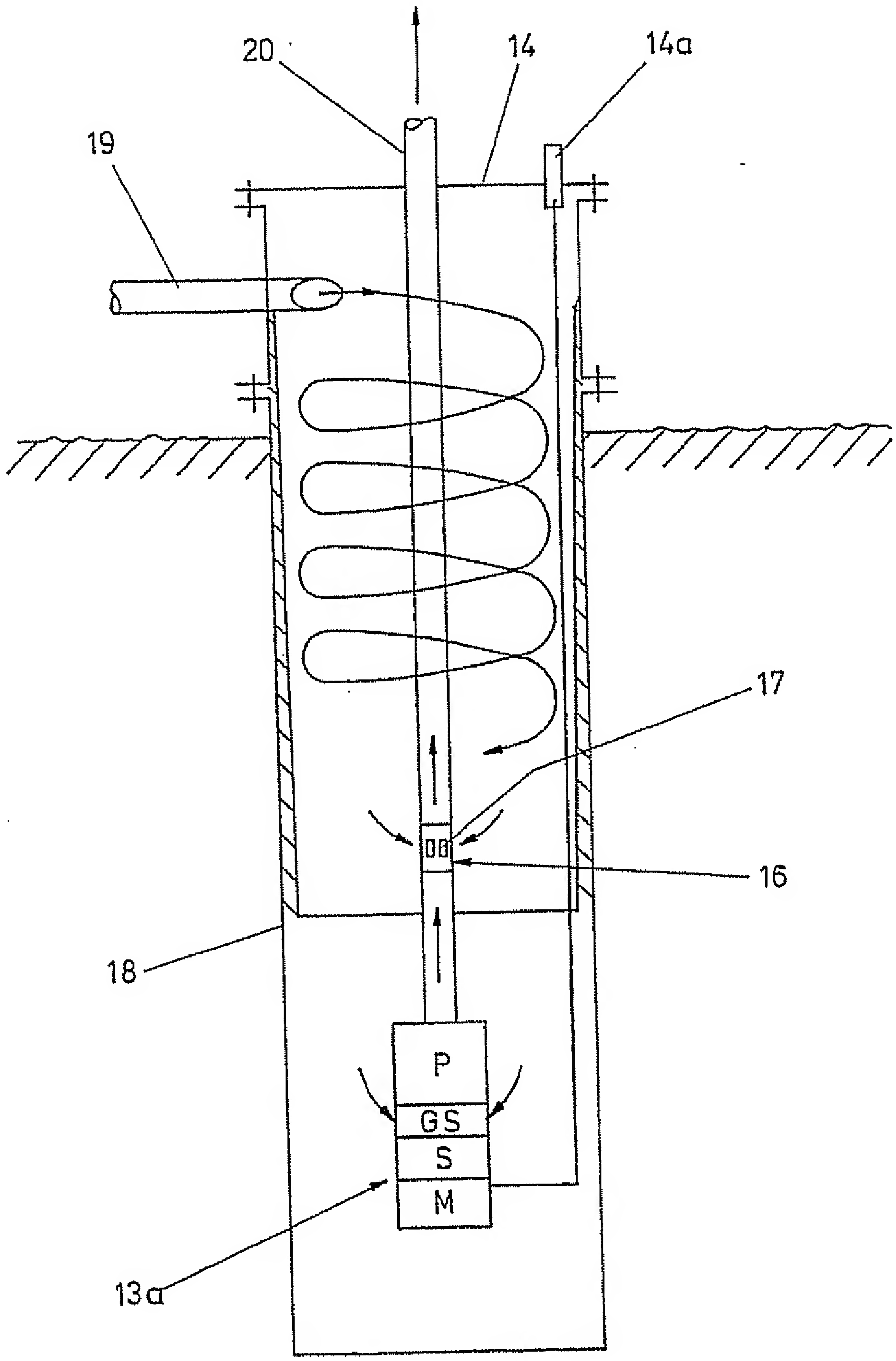

FIG. 4

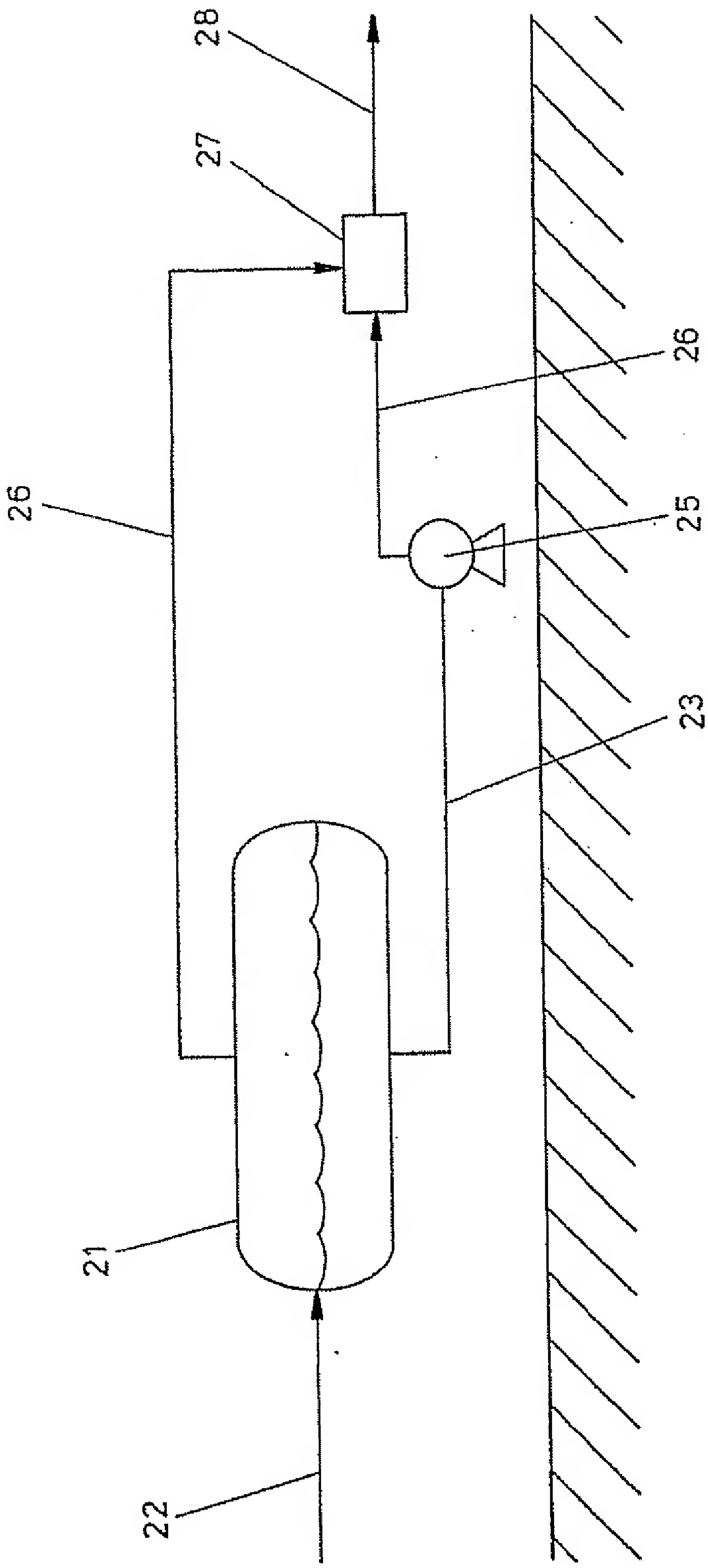

FIG. 5

MULTI-PHASE PUMPING

This invention relates to a pumping arrangement for pumping gaseous and liquid phase products, such as the products derived from an underground reservoir of oil and gas.

In the extraction of crude oil from underground reservoirs e.g. from below the seabed of the North Sea, it is usual for the crude oil to be accompanied by gaseous hydrocarbons, and indeed it is the presence of the gaseous hydrocarbons which gives rise to the reservoir pressure which drives the crude oil up a production pipe to a surface collection / process plant.

In the early stages of extraction of oil from a new production reservoir, the reservoir pressure usually is sufficient to drive the oil upwardly at acceptable production rates, but with the passage of time the pressure declines and therefore the production rate falls progressively with time, unless steps are taken to increase the rate of uplift by artificial means.

It is therefore usual to employ a pump to improve the rate of uplift of oil (and gas), and these comprise a so-called ESP (electrical submersible pump) which is arranged within the wellbore and immediately above the reservoir. The pump is a centrifugal type pump, and usually the pump is designed specifically for handling either gas, or liquid, but not a mixture of the two.

Accordingly, in the provision of artificial uplift of reservoir liquids (crude oil and often water as well), and which includes a significant volume fraction of gas, normal designs of ESP are unsuitable for this task. Thus, a centrifugal pump designed primarily for handling liquids cannot operate satisfactorily when large amounts of gas are present, since this can cause gas locking within the pump.

The present invention has therefore been developed with a view to improving the pumping of liquid / gaseous phase mixtures, and particularly, though not exclusively, in the

application of a novel pumping arrangement for uplifting crude oil / gaseous hydrocarbon mixtures from underground reservoirs.

Existing designs of ESP and application to the artificial uplifting of oil / gas mixtures will now be described with reference to Figures 1 and 2 of the accompanying drawings, to set out the background to the present invention and the problems to be solved. Figure 1 shows a common completion design for ESP in a low GOR (gas / oil ratio) well, and Figure 2 shows a high GOR application.

An ESP assembly typically consists of three main components, namely an electric motor, a centrifugal pump driven by the motor, and a sealing section which separates the motor from the pump. The purpose of the sealing section is to isolate the well fluids (liquids and gases) from the electric motor, while ensuring that the differential pressure between the wellbore and the inside of the motor is minimised. This, in effect, minimises the chances of wellbore fluid entering the motor (which could cause the motor to short circuit). Further, the sealing section enables torque to be transmitted from the motor to the pump.

In high gas / oil ratio wells (high GOR application) i.e. a gassy well, a gas separator is fitted between the sealing section and the pump. This separates the free gas from the oil, such that mainly oil is ingested into the pump, thereby eliminating the possibility that gas locking will occur within the pump.

ESP completions can be divided into two categories, namely those suitable for (1) high GOR (gassy) oils and (2) low GOR wells. In both cases, the ESP assembly is usually located just above the reservoir.

A typical low GOR completion is shown in Figure 1, which shows a production casing 10 running upwardly from reservoir 11, and containing a production tubing 12 within the casing 10, at the lower end of which is an ESP assembly 13. A so-called deep-set packer 14 is arranged within production casing 10 near the bottom end thereof i.e. spaced

a short distance above the assembly 13, and this serves to exclude hydrocarbon gas from coming into contact with the major part of the length of electrical power cable 15 running from the surface within casing 10 to supply power to motor M of the assembly 13.

Oil is pumped from reservoir 11 into the bottom of casing 10 and passes into the intake of the ESP assembly 13 and it then is subsequently pumped up the production tubing 12 to the surface. Little, if any, gas is present below the packer 14, since the intake pressure is normally maintained above "bubble point" pressure. The annular space within casing 10 above the packer 14 is usually filled with "completion brine", and since this does not contain hydrocarbons, this forms an ideal environment for power cable 15. Only a short length of the cable 15 below the packer 14 (usually approximately 100 foot long), is exposed to hydrocarbons, and this is normally oil, or an oil / water mixture, since free gas bubbles will not normally be present in view of the wellbore pressure at the intake of the ESP assembly 13 exceeding the bubble point pressure.

The low GOR completion design of existing type shown in Figure 1 has the following advantages:

1. Exposure of the power cable to hydrocarbons is minimised by use of the deep-set packer 14, and with completion brine being present in the annulus above the packer.

2. The deep-set packer aids "well kill" during workover.

3. Contact of corrosive produced fluids with the production casing is minimised.

A typical high GOR completion design of existing type is shown in Figure 2. In this arrangement, it is necessary to have a shallow set packer 14a, and which also contains a gas vent / annulus safety valve. Oil and free gas are produced from the reservoir 11 and flow up to ESP assembly 13a which comprises, in addition to motor M, seal S and pump P, a gas separator GS. The detail view shows the function of

the gas separator, and how gas is separated from the oil / gaseous mixture, and with the oil (and water) passing upwardly through production tubing 12. Thus, at the gas separator GS, the gas is separated and flows up the annular space defined between production casing 10 and production tubing 12.

The oil and water liquid phase which passes from the gas separator to the pump P then has its pressure increased, and then travels upwardly through the tubing 12 to process plant at the surface. In the high GOR well arrangement shown in Figure 2, all of the power cable 15 is exposed to hydrocarbons.

There are a number of disadvantages associated with this design:

1. The majority of the electrical power transmission system is exposed to produced fluids.

2. The completion is complicated by additional safety valves.

3. A large amount of the casing is exposed to potentially corrosive produced fluids.

4. Additional surface pipeline is required at the surface to handle the separated gas.

5. Killing operations during workover are made more difficult by the large hydrocarbon volume below the dual packer.

The present invention seeks to provide an improved means of handling and pumping liquid / gaseous phase mixtures.

Accordingly, the present invention provides a pump arrangement for pumping a liquid / gaseous phase mixture from an underground reservoir to a process plant, said pump arrangement being positionable in a flow line running between the reservoir and the process plant and comprising:

a liquid / gas separator having an intake for receiving an input supply of the liquid / gaseous phase mixture, and arranged to deliver separated outputs of liquid and gas;

a motor-driven liquid pump arranged to receive the

liquid output from the separator, and to discharge a pumped output of liquid:

a jet pump arranged to receive the pumped output of liquid, and to pass the liquid through the pump prior to discharge of the liquid e.g. into a production pipe, after undergoing a pressure reduction by the jet pump: and.

a gas inlet to said jet pump which is communicable with the gas output of the separator whereby the gas can be ingested into the jet pump by the pressure reduction so as to co-mingle with the liquid and be movable with the discharge flow of liquid from the jet pump.

The invention therefore enables any suitable type of liquid pump to be used e.g. an electrically driven centrifugal pump to handle the liquid phase of the reservoir product, whereas the gaseous phase can be ingested into the jet pump downstream of the liquid pump, by reason of the pressure reduction applied to the pumped liquid in its passage through the jet pump.

In one preferred arrangement, an ESP module is provided which comprises a motor, a seal, a gas / liquid separator and a liquid pump, and which may be mounted in a lower end of a production casing extending upwardly from the reservoir to a surface distribution arrangement, and which is arranged to receive an intake of liquid / gas mixture from the reservoir, to separate the liquid and gaseous phases, to pass the liquid through the liquid pump, and to cause the separated gas to by-pass the pump and to be fed to the gas inlet of a jet pump mounted in the production pipe running upwardly within the production casing.

In a further preferred arrangement, a similar ESP module may be mounted in the production casing, but the liquid / gaseous phase product may be fed to the module via an inlet to the casing arranged above the module and directed such that a spirally downward flow takes place within the casing, during which time the liquid phase tends to separate from the gaseous phase and falls under gravity towards the intake of the assembly, whereas the separated gaseous phase

is ingested via the inlet of the jet pump to co-mingle with the upwardly pumped flow of liquid.

In a still further preferred arrangement, adapted to be arranged above the reservoir e.g. on the seabed, the reservoir product is first fed to a gas / liquid separator, the separated liquid phase is then conveyed to a liquid pump where it receives a pumping action and is then conveyed onwardly to a jet pump, whereas the separated gaseous phase bypasses the liquid pump and is ingested via the jet pump inlet to co-mingle with the pumped liquid and which are then conveyed onwardly to a discharge pipe at a reduced pressure.

Preferred embodiments of the invention will now be described in detail, by way of example only, with reference to Figures 3 to 5 of the accompanying drawings, in which:

Figure 1 is a schematic vertical sectional illustration of a first embodiment of pump arrangement according to the invention for use in a high GOR well;

Figure 4 is a similar view of a further embodiment of pumping arrangement according to the invention; and,

Figure 5 is a schematic illustration of a pumping arrangement layout according to a still further embodiment of the invention, arranged above a reservoir and on the seabed.

Referring now to Figures 3 to 5 of the drawings, there will be described embodiments of pumping arrangement for pumping a liquid / gaseous phase mixture from an underground reservoir to a process plant, in which the pump arrangement is positionable in a flow line running between the reservoir and the process plant. The pump arrangement comprises a liquid / gas separator having an intake for receiving an input supply of the liquid / gaseous phase mixture, and arranged to deliver separated outputs of liquid and gas, a motor-driven liquid pump arrangement to receive the liquid output from the separator and to discharge a pumped output of liquid, a jet pump arranged to receive the pumped output of liquid and to pass the liquid through the pump prior to discharge of the liquid e.g. into a production pipe, after undergoing a pressure reduction by the jet pump, and a gas

inlet to the jet pump which is communicable with the gas output of the separator whereby the gas can be ingested into the jet pump by the pressure reduction therein so as to co-mingle with the liquid and be movable with the discharged flow of liquid from the jet pump.

Referring first to Figure 3 of the drawings, parts corresponding with those already described are given the same reference numerals, and will not be described in detail again. An ESP module 13a is mounted below production pipe 12, at the lower end of production casing 10 and immediately above the reservoir 11, and comprising pump P, gas separator GS, seal S and electrically operated motor M. This embodiment is suitable for use in a high GOR well, and enables a deep-set packer 14 to be used. The liquid / gaseous phase product from reservoir 11 passes upwardly to the module 13a, and the separator GS separates the gaseous phase which is liberated as gas bubbles and which by-pass the liquid pump P, whereas the liquid phase passes directly to the pump P and is then pumped upwardly through production pipe 12 towards a jet pump 16. The pumped liquid flow from pump P passes upwardly through the jet pump 16, a detail of which is shown to an enlarged scale, and it undergoes a pressure reduction as it passes through the jet pump 16, before issuing as a discharged flow of liquid into the production pipe 12. The separated gaseous phase by-passes the liquid pump P and moves upwardly into the annular chamber located below packer 14 and surrounding production pipe 12, and is ingested through gas inlets 17 of the jet pump 16 by virtue of the pressure reduction generated by the upwardly flowing liquid, and this gas co-mingles with the liquid and then moves with the discharge flow of liquid from the jet pump upwardly within the production pipe 12.

The gaseous hydrocarbons are kept remote from the major part of the electrical power cable 15, and this is a safety aspect, and the liquid pump P only exerts a pumping action on the liquid phase of the reservoir product. The co-mingled liquid / gaseous phase product is then discharged upwardly

within the production pipe 12 to any suitable distribution arrangement at the surface, and then onwardly to any suitable processing plant. The oil / gas mixture can be conveyed by a single pipeline to any suitable land installation.

In a preferred arrangement, the jet pump 16 is arranged to be wireline retrievable, and to be locked into a nipple profile. This enables hydraulic communication between the annulus and the tubing, thereby enabling the gas to be ingested into the jet pump.

A further embodiment is shown in Figure 4, and this may comprise a surface or seabed installation. Typically, the device would be located adjacent to or in the vicinity of the wellhead i.e. on the surface or on the seabed. The pumping assembly could be located e.g. in a short piece of casing, say 300 feet deep.

An ESP assembly 13a consisting of motor M, seal S, gas separator GS and liquid pump P is contact within the casing 18, and this assembly receives the reservoir product, which is comprised mainly of liquid phase, via the gas separator GS and the liquid phase then passes to the pump P and is then pumped upwardly towards jet pump 16. Any gaseous phase admitted by the gas separator GS is separated, and then bubbles upwardly to the inlet 17 of jet pump 16. As in the previous embodiment, the jet pump 17 ingests and compresses the free gas liberated by the gas separator.

However, in this embodiment, further separation of the liquid and gaseous phases takes place, in that a tangential inlet 19 to the casing 18 is arranged above the ESP module 13a, and directs a spirally downward flow of the reservoir product, as shown schematically in Figure 4, and during this movement the liquid phase separates from the gaseous phase and falls under gravity towards the intake of the ESP assembly 13a, whereas the separated gaseous phase is ingested by the inlet 17 of the jet pump 16 to co-mingle with the upwardly pumped flow of liquid.

Thus, some separation of gas / liquid takes place in the void above the assembly 13a, but any remaining gas which

passes with the liquid phase to the gas separator GS is then separated out. and by-passes the pump P as described already. The pump compresses the oil. whilst the jet pump 16. which is effectively powered by the pressurised liquid delivered by the module 13a. ingests and then compresses the gas. The resulting multi-phase gas / liquid mixture then exits the unit into the discharge pipe 20 within casing 18 at a greater pressure than the supply pressure to inlet 19.

It should be noted that. although Figure 4 illustrates a sub-sea application. and this embodiment could also have application on land. platforms or any location where multi-phase pumping is required.

A further preferred embodiment is shown in Figure 5. which has a conventional gas / liquid separator 21 which has an intake of liquid / gaseous phase product via input line 22. This may comprise a standard gas / liquid separator, and which receives a low pressure multi-phase (oil, water and free gas) mixture from the flowing well. and separated liquid is discharged via line 23 and separated free gas exits via line 24.

A standard liquid duty pump 25 boosts the pressure of the liquids from line 23. and discharges this into output line 26. Jet pump 27 is arranged downstream of pump 25. and uses the high pressure liquid supply as the power fluid which undergoes pressure reduction. whereby gas from low pressure line 24 is ingested into jet pump 27. The co-mingled gas / liquids are then discharged to discharge pipe 28 at a pressure significantly greater than the pressure in supply line 22.

Typically. the pressure in lines 23 and 24 may be 100 psi. whereas pressure in output line 26 from liquid pump 25 may be 3.000 to 4.000 psi. The resulting pressure of the co-mingled liquid / gaseous phase in discharge line 28 might be, say. 2.000 psi.

Although shown in a sub-sea application. this device also could be used on land. platforms; or any location where multi-phase pumping is required.

CLAIMS

1. A pump arrangement for pumping a liquid / gaseous phase mixture from an underground reservoir to a process plant, said pump arrangement being positionable in a flow line running between the reservoir and the process plant and comprising:

a liquid / gas separator having an intake for receiving an input supply of the liquid / gaseous phase mixture, and arranged to deliver separated outputs of liquid and gas;

a motor-driven liquid pump arranged to receive the liquid output from the separator, and to discharge a pumped output of liquid;

a jet pump arranged to receive the pumped output of liquid, and to pass the liquid through the pump prior to discharge of the liquid e.g. into a production pipe, after undergoing a pressure reduction by the jet pump; and,

a gas inlet to said jet pump which is communicable with the gas output of the separator whereby the gas can be ingested into the jet pump by the pressure reduction so as to co-mingle with the liquid and be movable with the discharge flow of liquid from the jet pump.

2. A pump arrangement according to Claim 1, in which the motor-driven liquid pump is an electrically driven centrifugal pump.

3. A pump arrangement according to Claim 1 or 2, in which an ESP module is provided which comprises a motor, a seal, a gas / liquid separator and a liquid pump, and which is adapted to be mounted in a lower end of a production casing extending upwardly from the reservoir to a surface distribution arrangement.

4. A method of pumping a liquid / gaseous phase mixture from an underground reservoir to a process plant, using a pump arrangement according to Claim 3, in which the ESP module receives an intake of liquid / gas mixture from the reservoir, separates the liquid and gaseous phases, passes the liquid through the liquid pump, and causes the

separated gas to by-pass the pump and to be fed to the gas inlet of a jet pump mounted in the production pipe running upwardly within the production casing.

5. A method pumping a liquid / gaseous phase mixture from an underground reservoir to a process plant, using an ESP module as claimed in Claim 3, in which the liquid / gaseous phase product is fed to the module via an inlet to the casing arranged above the module and directed such that a spirally downward flow takes place within the casing, during which the time the liquid phase tends to separate from the gaseous phase and falls under gravity towards the intake of the assembly, whereas the separated gaseous phase is ingested via the inlet of the jet pump to co-mingle with the upwardly pumped flow of liquid.

6. A method of pumping a liquid / gaseous phase mixture from an underground reservoir to a process plant using a pump arrangement positioned in a flow line running between the reservoir and the process plant and said pump arrangement comprising:

a liquid / gas separator having an intake which receives an input supply of the liquid / gaseous phase mixture, and delivers separated outputs of liquid and gas;

a motor-driven liquid pump which receives the liquid output from the separator, and discharges a pumped output of liquid;

a jet pump which receives the pumped output of liquid, and passes the liquid through the pump prior to discharge of the liquid e.g. into a production pipe, after undergoing a pressure reduction by the jet pump; and

a gas inlet to the jet pump which communicates with the gas output of the separator whereby the gas is ingested into the jet pump by the pressure reduction so as to co-mingle with the liquid and to move with the discharge flow of liquid from the jet pump.

7. A method according to Claim 6, in which the reservoir product is first fed to a gas / liquid separator, the separated liquid phase is then conveyed to a liquid pump

where is receives a pumping action and is then conveyed onwardly to a jet pump, whereas the separated gaseous phase by-passes the liquid pump and is ingested via the jet pump inlet to co-mingle with the pump liquid and which are then conveyed onwardly to a discharge pipe at a reduced pressure.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

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(ii) Int Cl (Edition 5) F04D 13/00, 13/10, 13/12, 13/16; 31/00; F04B 23/08, 23/14

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Search Examiner

M D WALKER

Date of Search

28 APRIL 1993

Documents considered relevant following a search in respect of claims ALL

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2239676 A (BHR GROUP) Figure 1; page 1, line 18 etc	1, 2, 4
Y	GB 2239676 A	6, 7
X	GB 2208411 A (PLESSEY) Figure 1 and note separator 17, pump 8 and jet pump 13	1 at least
X	US 4294573 (ERICKSON) Column 3, line 48 onwards	1-4, 6
Y	US 4294573	7

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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